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Title: MHD For NRL Visit

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MHD For NRL Visit

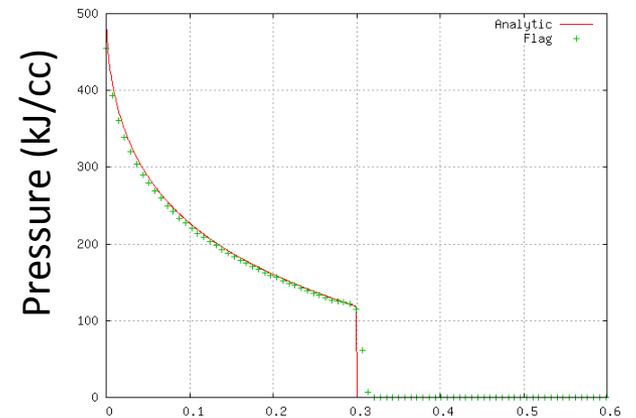
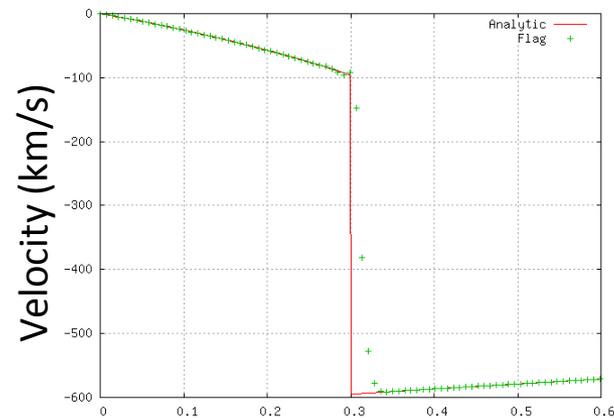
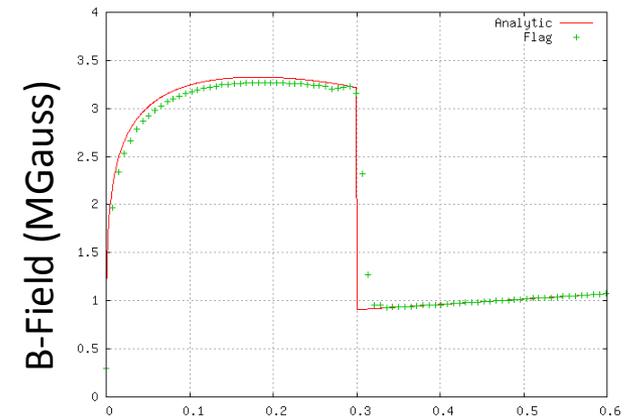
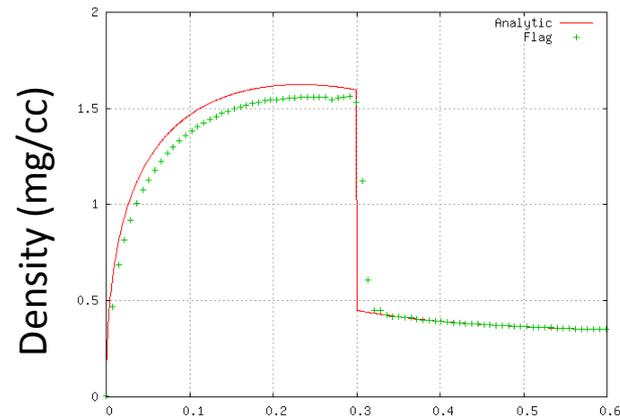
C. L. Rousculp (XCP-6)

24 Aug 2017

First Magnetic Noh Verification Problem

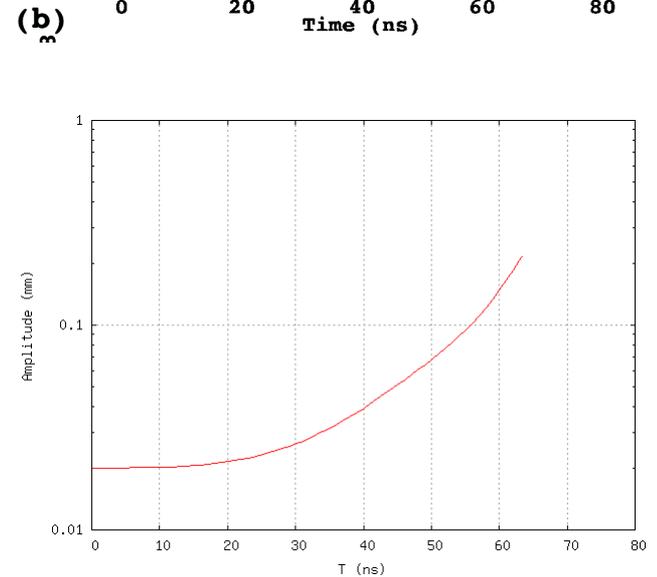
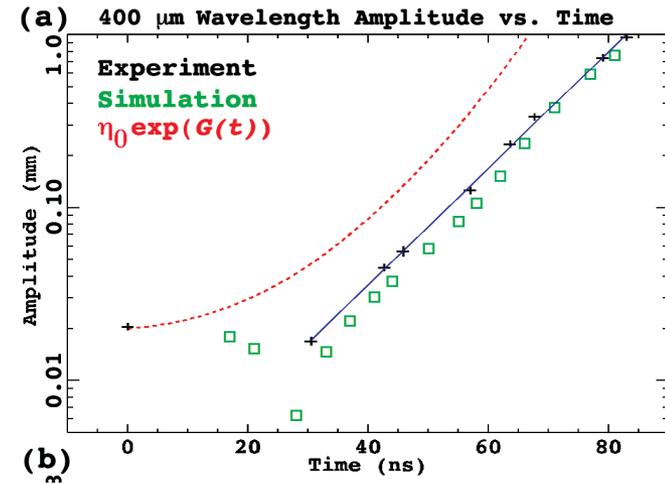
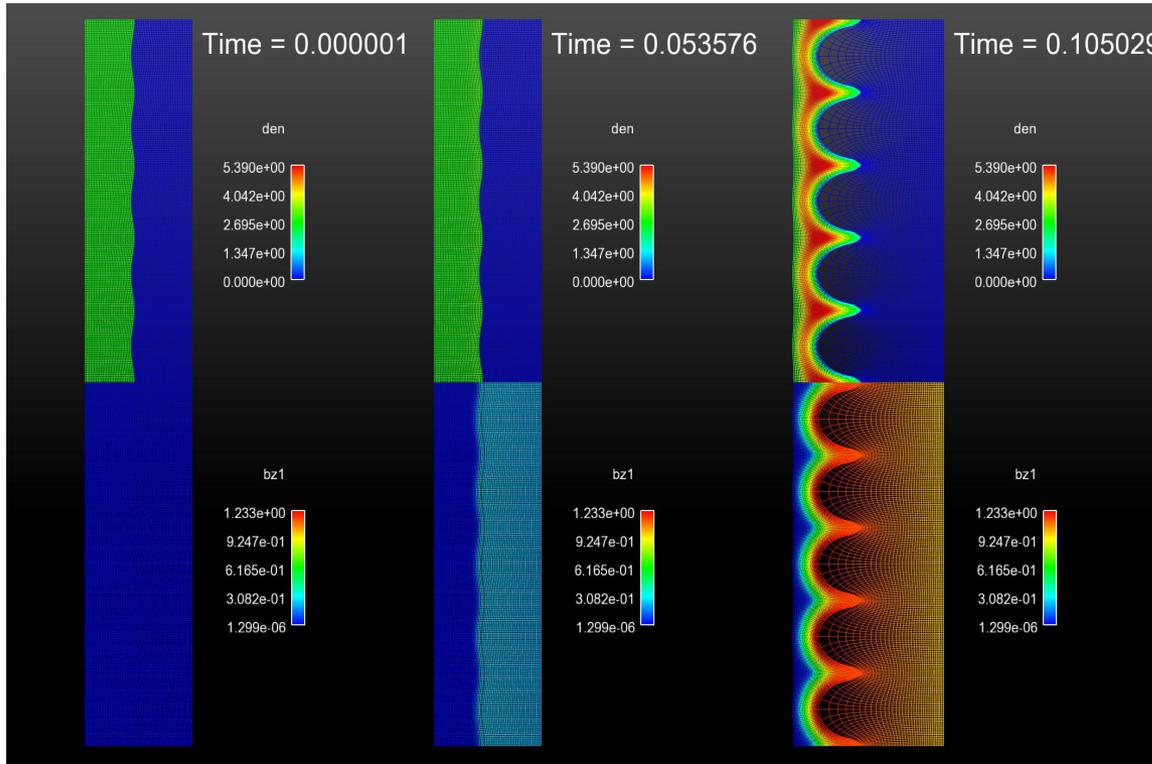
- $B(0) = B_0 r$
- $\rho(0) = \rho_0 r^2$
- $V(0) = -V_0$
- $P(0) = 10^{-6} U_{\text{mag}}$

- $B_0 = 0.635584 \text{ MG}$
- $\rho_0 = 3.1831 \times 10^{-5} \text{ g/cc}$
- $V_0 = 32.4010 \text{ cm}/\mu\text{s}$



R (cm)

Sandia-Z Magnetic Rayleigh Taylor Experiments*



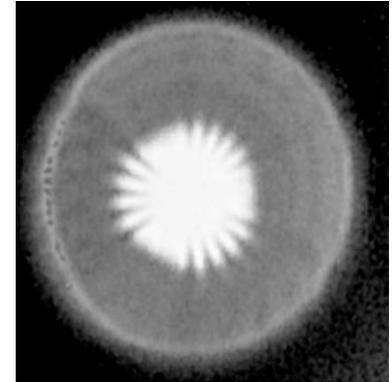
*Sinars et al., PRL, 2010

$\lambda = 400 \mu\text{m}$
 $A = 20 \mu\text{m}$
 $R = 3.168 \text{ mm}$
 $dr = 292 \mu\text{m}$

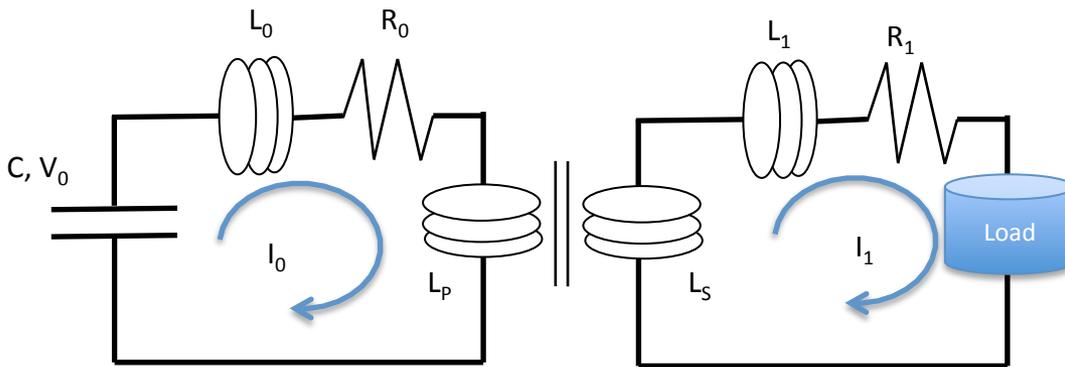
PHELIX Circuit Models



pRad Image of RMI

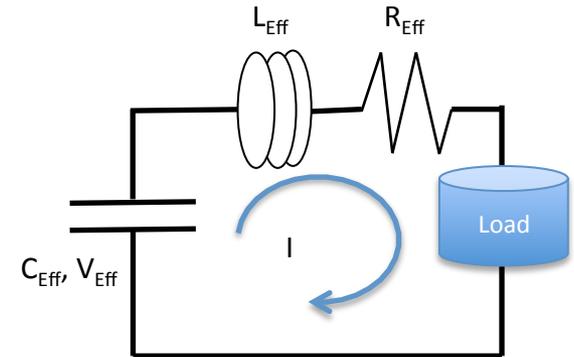


2-Loop Transformer Model (RAVEN)



$$L_M = k\sqrt{L_P L_S}$$

1-Loop LRC (RAVEN, FLAG)



2 Loop Transformer Eqns

Coupled 2 Loop Eqns with Mutual Inductance L_M

$$L_M \dot{I}_1 + (L_0 + L_p) \dot{I}_0 = -R_0 I_0 + V_c$$

$$L_M \dot{I}_0 + (L_1 + L_s) \dot{I}_1 = -R_1 I_1$$

$$\dot{V}_c = I_0 / C$$

For $R_1 \ll R_0$

A good assumption for solid-state liners

Single Loop for the Primary Current

$$L_{effective} \dot{I}_0 = -R_0 I_0 + V_c$$

$$\dot{V}_c = I_0 / C$$

$$L_{effective} = L_0 + L_p - \frac{L_M^2}{L_1 + L_s}$$

Single Loop for the Secondary Current

$$L_{effective} \dot{I}_1 = -R_{effective} I_1 + V_{effective}$$

$$\dot{V}_{effective} = I_1 / C_{effective}$$

$$L_{effective} = \frac{(L_0 + L_p)(L_1 + L_s)}{L_M} - L_M$$

$$R_{effective} = R_0 \frac{L_1 + L_s}{L_M}$$

$$C_{effective} = C \frac{L_M}{L_1 + L_s}$$

$$V_{effective} = -V_c$$

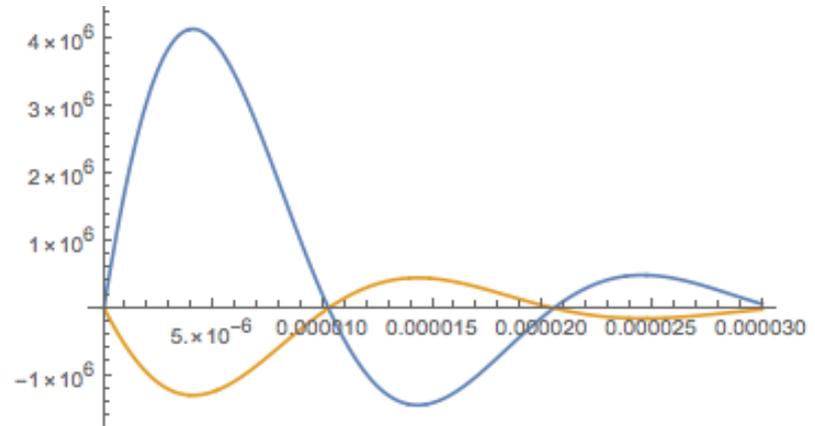
For codes with only a single loop circuit model

PHELIX Static Load Example

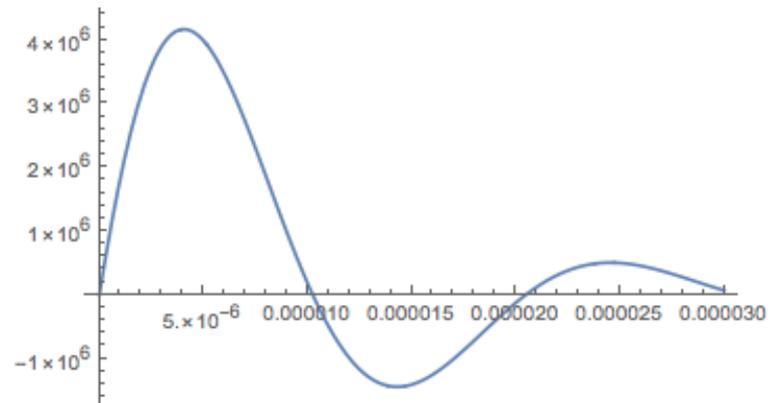
PHELIX Parameters

	(nH, uF, mO, kV)		
L0	40		
LP	390		
L1	4		
LS	24.3		
C	68		
VC	100		
R0	29		
k	0.93		
M	90.53539253		
L1eff	140.3654664		
			Flag CU
L2eff	43.87613053		0.43876131
Ceff	217.5408725		21.7540873
Reff	9.064963183		0.09064963

Transformer Model Currents (A)



Single Loop LRC Model Secondary Current (A)



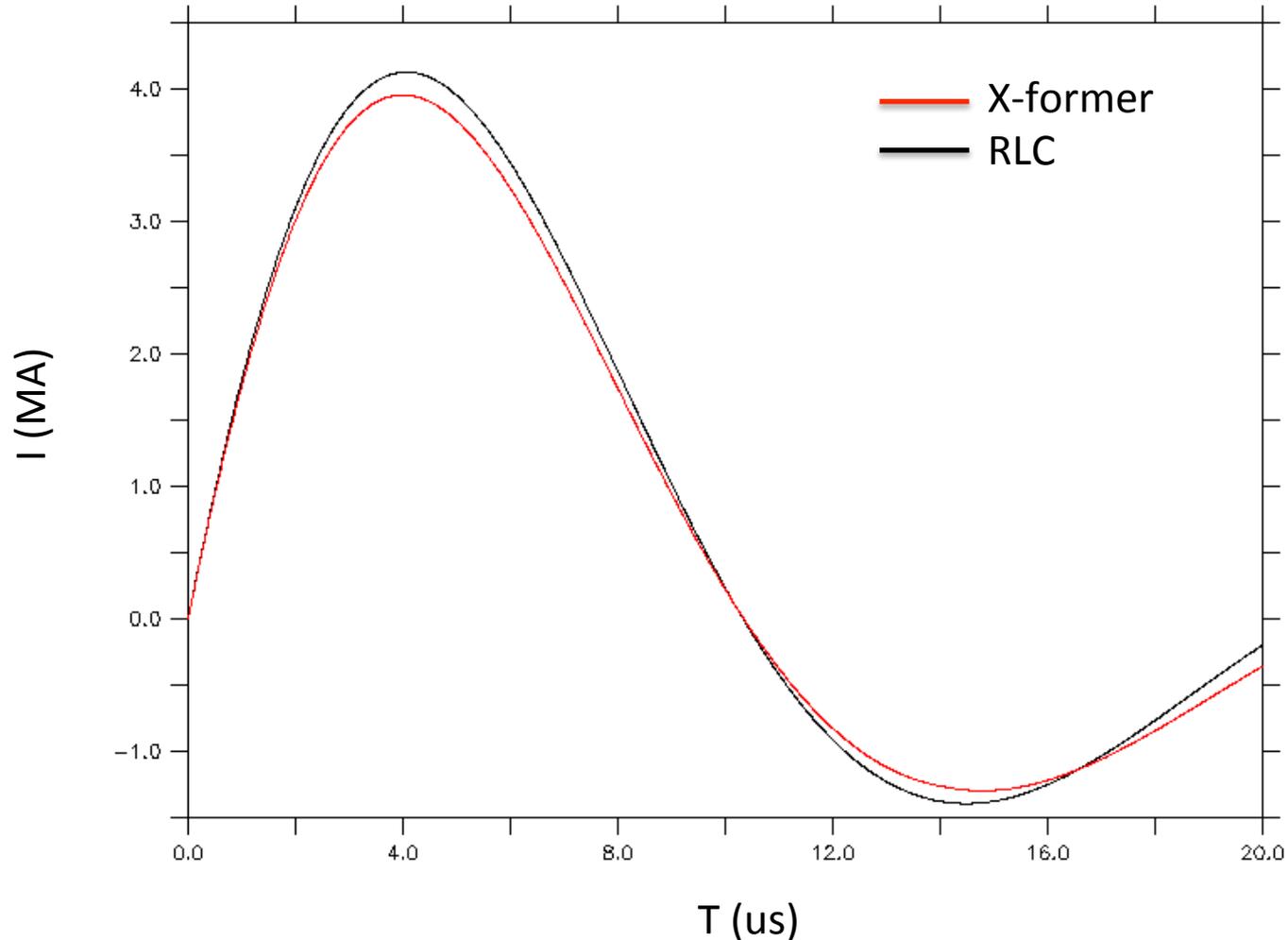
PHELIX EOS Experiment

- Sample OR = 1.270 cm
- Tgt Cylinder OR = 1.470 cm (dr = 2 mm)
- Liner IR = 2.170 cm (dr = 7 mm)
- Liner OR = 2.295 cm (dr = 1.25 mm)
- Insulator OR = 2.468 cm (dr = 1.73 mm)
- RC OR = 3.468 cm (dr = 1 cm)

- Height = 2 cm

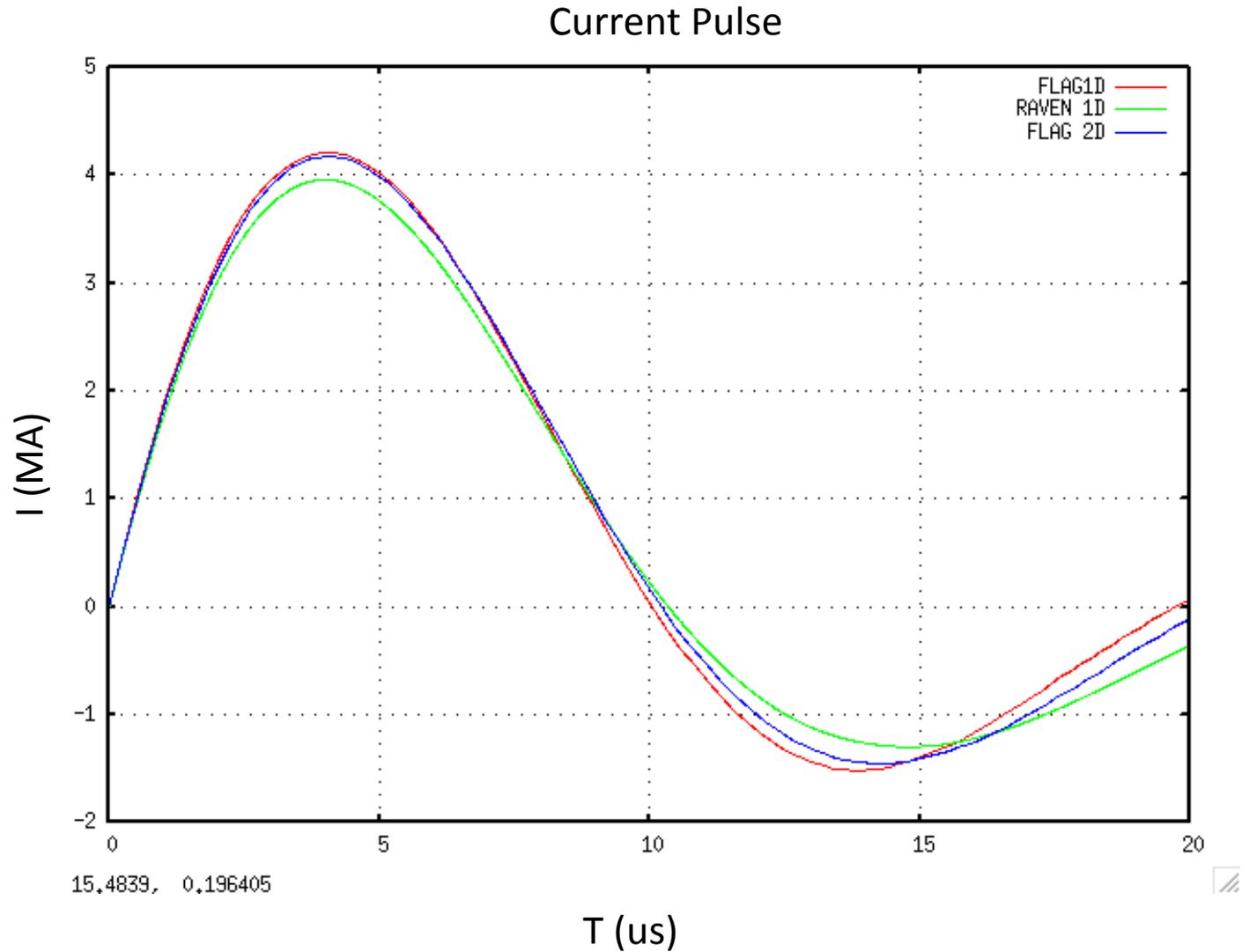
RAVEN 1D

X-former (2-loop) vs RLC (1-loop) Circuit Models

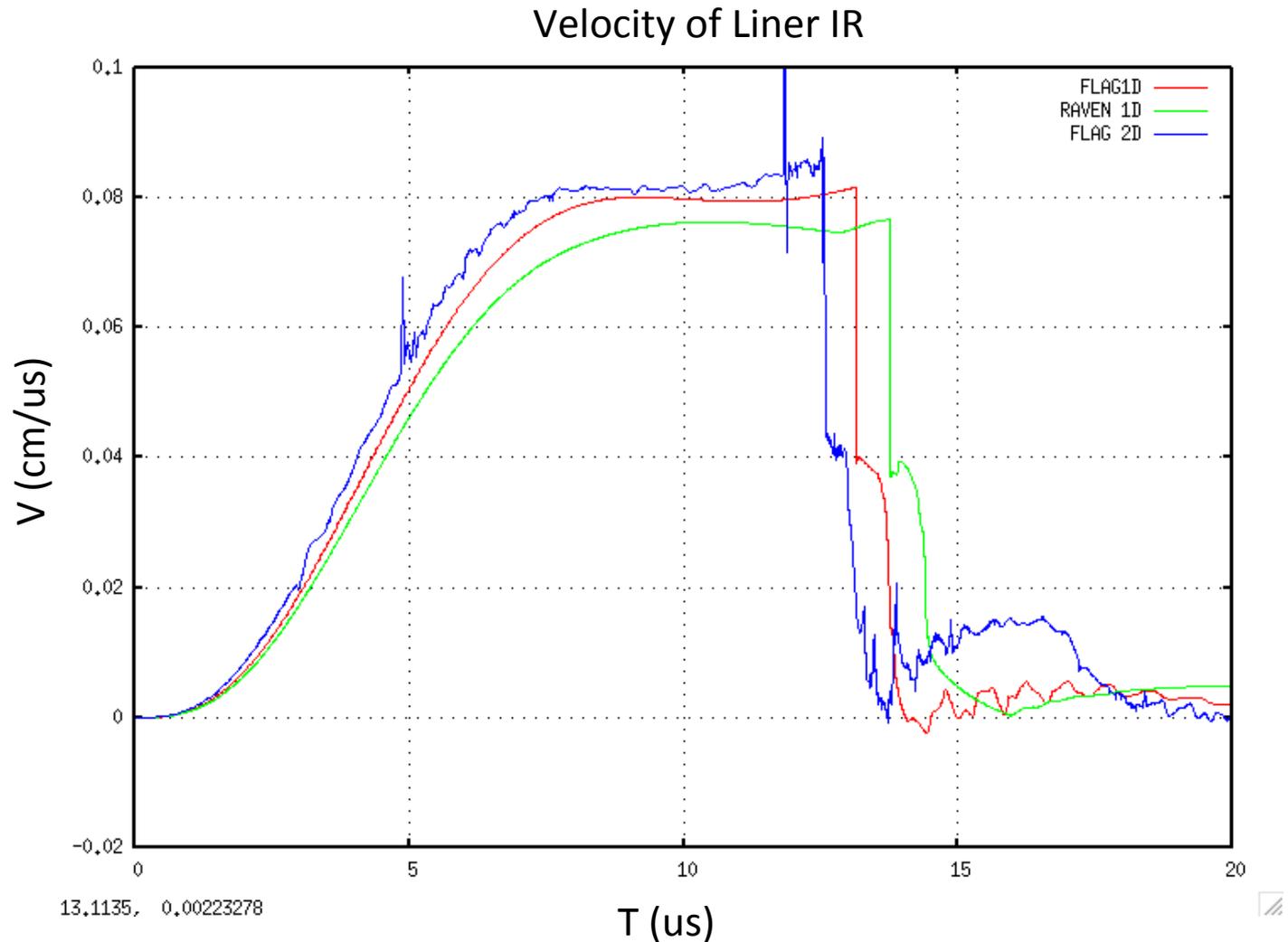


Show's that the dynamic inductance of the load affects each circuit differently

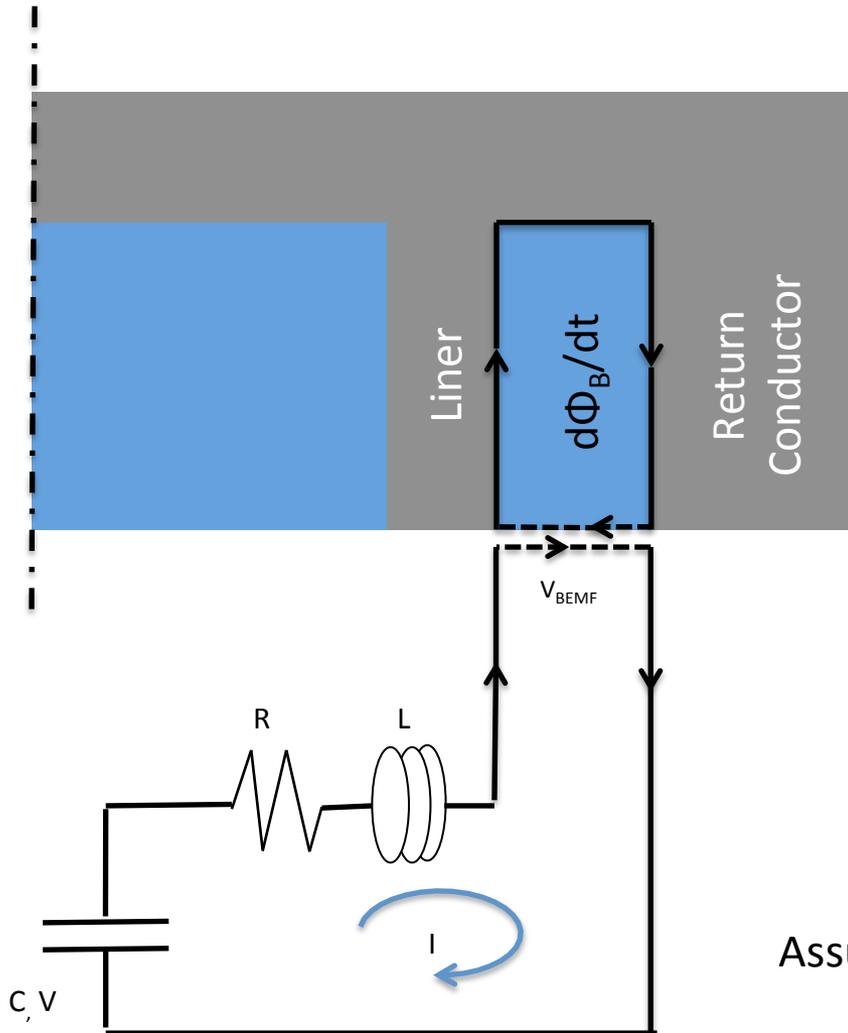
RAVEN (2-loop) vs FLAG 1D/2D (V = 90 kV)



RAVEN (2-loop) vs FLAG 1D/2D (V = 90 kV)



Single Loop LRC Circuit Model Coupling in FLAG



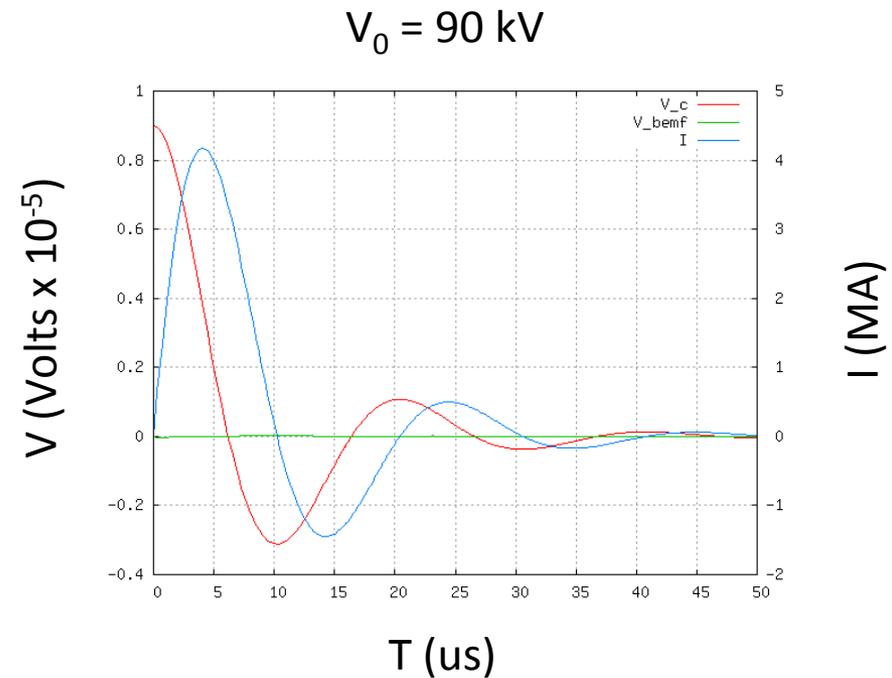
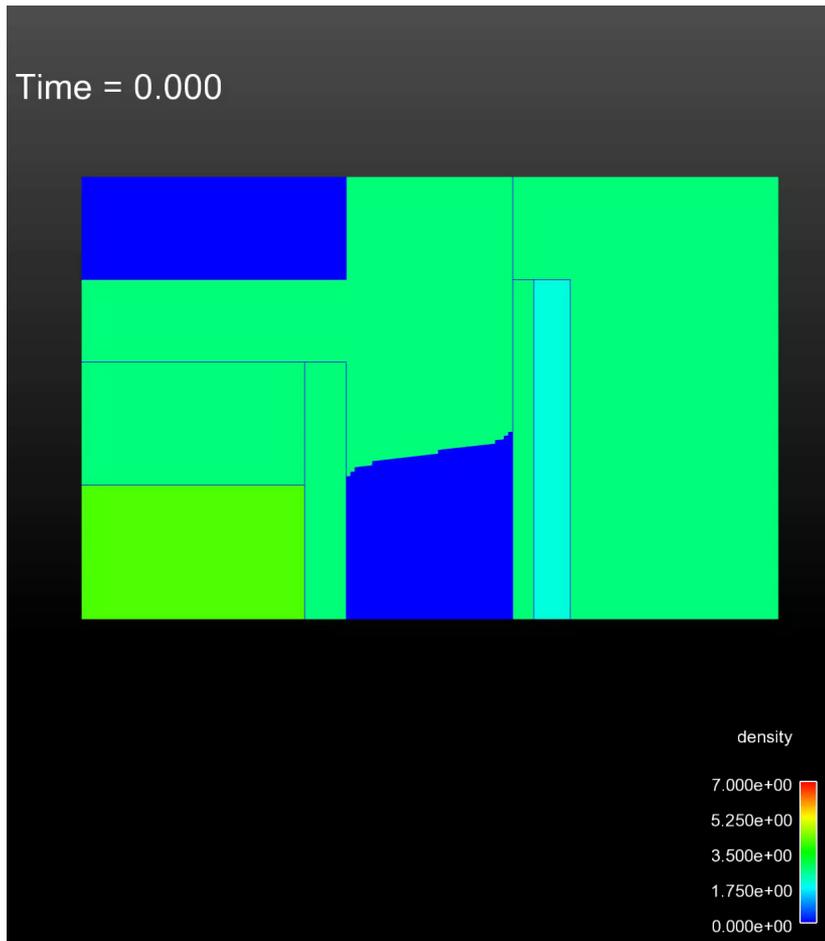
In a time-step

- Hydro
 - ALE – advection/remap
 - Solves momentum/energy + $J \times B$
- Circuit solver
 - Takes V_{BEMF} , V , R , L , C
 - Solves for I
- Magnetic Diffusion
 - Compute B on Boundary from I
 - Implicit Solver Updates B
 - Compute V_{BEMF}

$$V_{BEMF} = \oint E \cdot dl = -\frac{d}{dt} \int B \cdot dS = -\frac{d}{dt} \Phi_B$$

Assumes $E \cdot dl = 0$ along interface portion of the loop

2D FLAG Calculation of the EOS Experiment



V_{BEMF} is small in the PHELIX system,
but not in general

3D-MHD Package

Input Noh (Problem-3)

Field Specs

```
mk /global/mesh/field(radius)/analytic_func
kfunc = Expr( sqrt ( +(^(x 2) ^(y 2)) ) )
```

```
$mk /global/mesh/field(radius)/test
$ alias z_field_radius z_field
$ alias p_field_radius p_field
```

```
mk /global/mesh/field(rhoZero)/analytic_func
kfunc = Expr( *( RHO ^(radius *(2 ALPHA)) ) )
```

```
mk /global/mesh/field(pZero)/analytic_func
kfunc = Expr( *( PO ^(radius *(2 ALPHA)) ) )
```

```
mk /global/mesh/field(bfx)/analytic_func
kfunc = Expr( *(-1.0 BPHIO y ^(radius ALPHAM2)) )
```

```
mk /global/mesh/field(bfy)/analytic_func
kfunc = Expr( *( BPHIO x ^(radius ALPHAM2)) )
```

```
mk /global/mesh/field(bfz)/analytic_func
kfunc = Expr( *(BZO ^(radius ALPHAM1)) )
```

```
mk /global/mesh/field(tau)/analytic_func
kfunc = Expr( - (radius * (t V0)) )
```

```
mk /global/mesh/field(densityField)/analytic_func
kfunc = Expr( / ( *(radius rhoZero) tau ) )
```

```
$mk /global/mesh/field(energyField)/analytic_func
$ kfunc = Expr( / ( *(radius eZero) tau ) )
```

```
mk /global/mesh/field(energyField)/analytic_func
kfunc = Expr( 8.81129E+09 )
```

```
mk /global/mesh/field(bfxtau)/analytic_func
kfunc = Expr( *(-1.0 BPHIO y ^(tau ALPHAM2)) )
```

```
mk /global/mesh/field(bfytau)/analytic_func
kfunc = Expr( *( BPHIO x ^(tau ALPHAM2)) )
```

```
mk /global/mesh/field(bfztau)/analytic_func
kfunc = Expr( *(BZO ^(tau ALPHAM1)) )
```

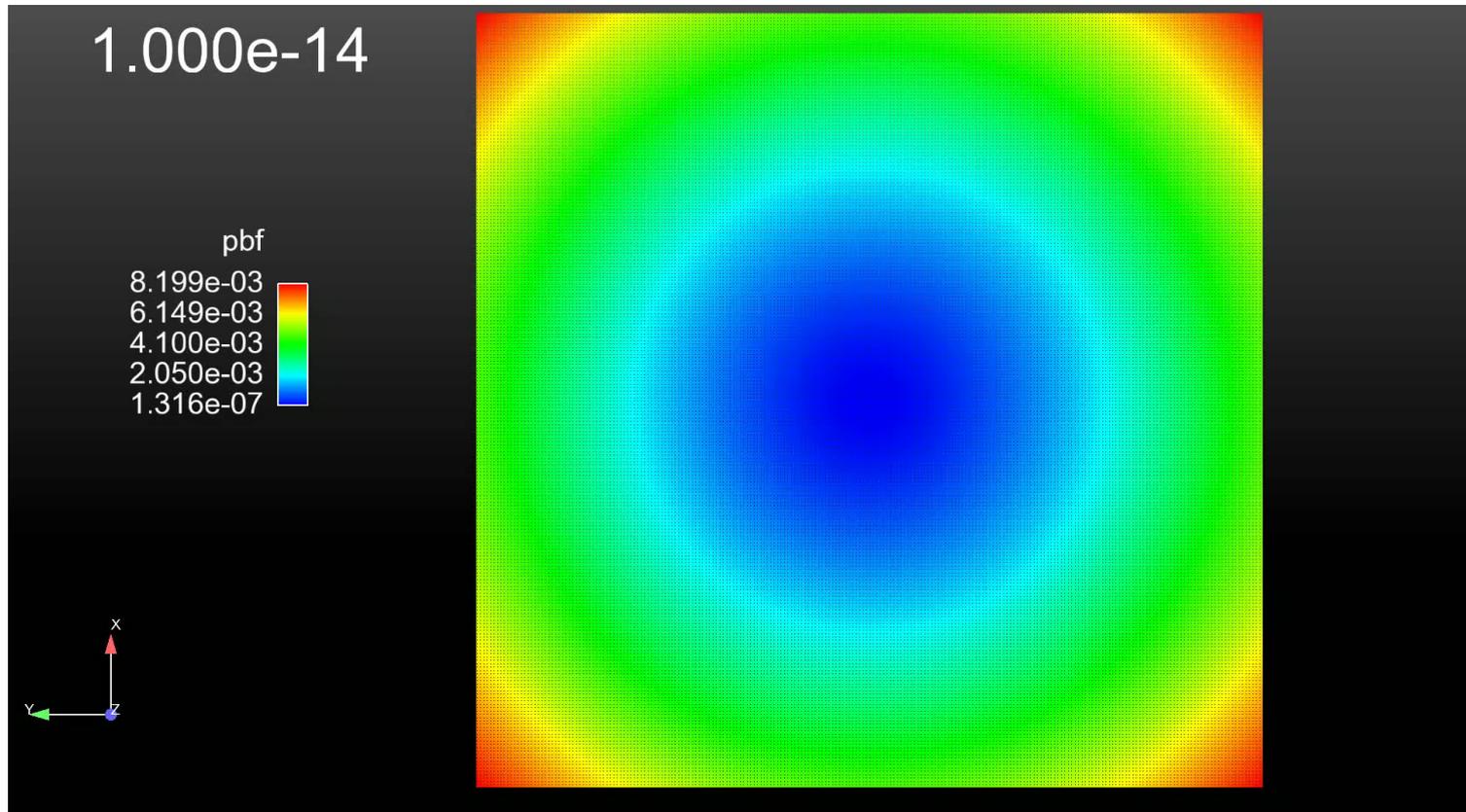
Material Inflow Specs

```
mk /global/mesh/optimize/ale/volrelax/euler/kbc(bc5)/kinflow
iensqsubset = 1
bdy = "bExterior"
matname="mat1"
tstart=0.0 "cgs"
imode = 22
r_field = "densityField"
e_field = "energyField"
$ density=1.6e-4 "cgs" ! do not set
$ energy=8.8e9 "cgs" ! do not set
```

Field Inflow Specs

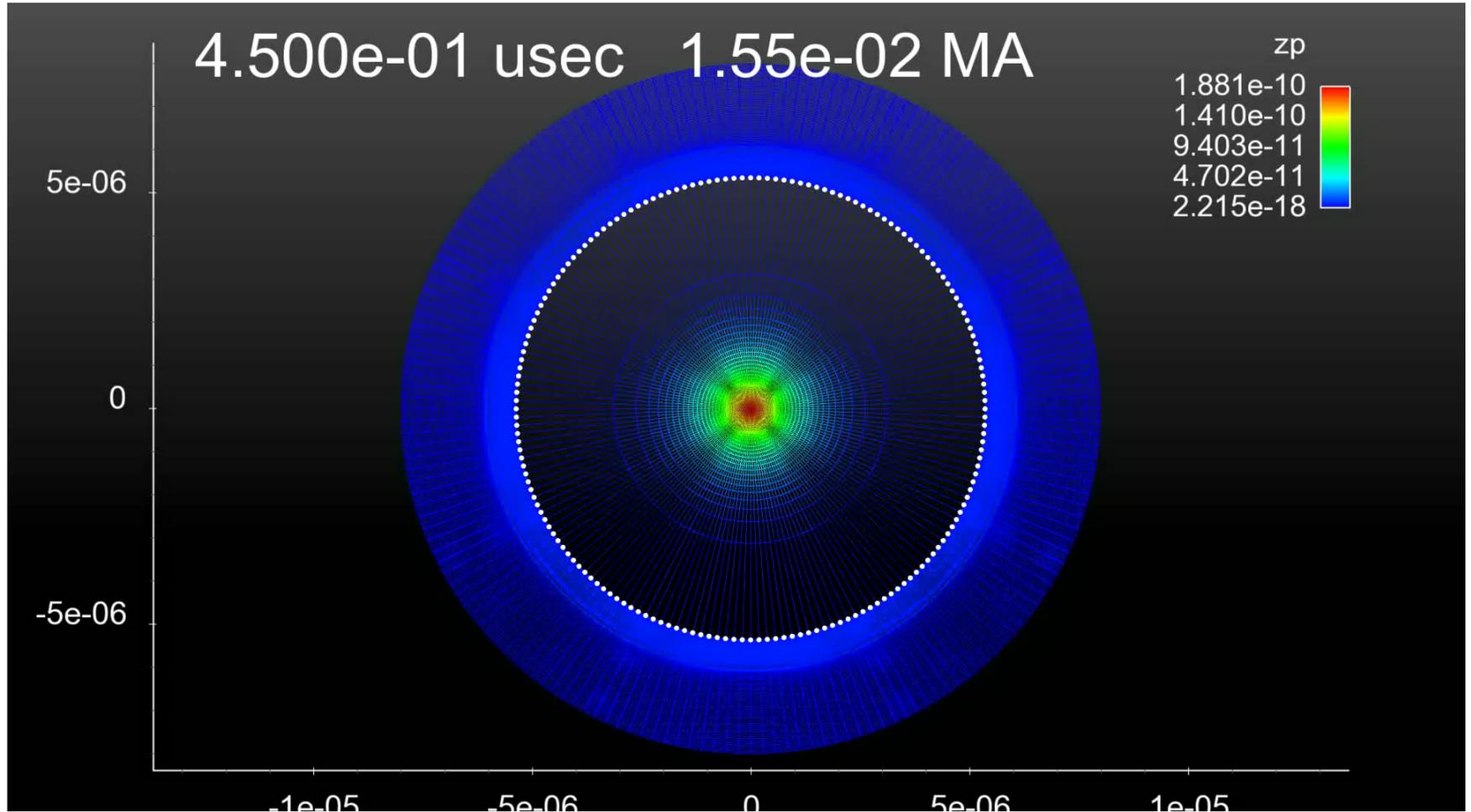
```
mk /global/mesh/mfield/mhd3d/boundary/z2d_inflow
bdy = "bExterior"
field_xyz(1) = "bfxtau"
field_xyz(2) = "bfytau"
field_xyz(3) = "bfztau"
```

3D-MHD Package Noh (Problem-3)

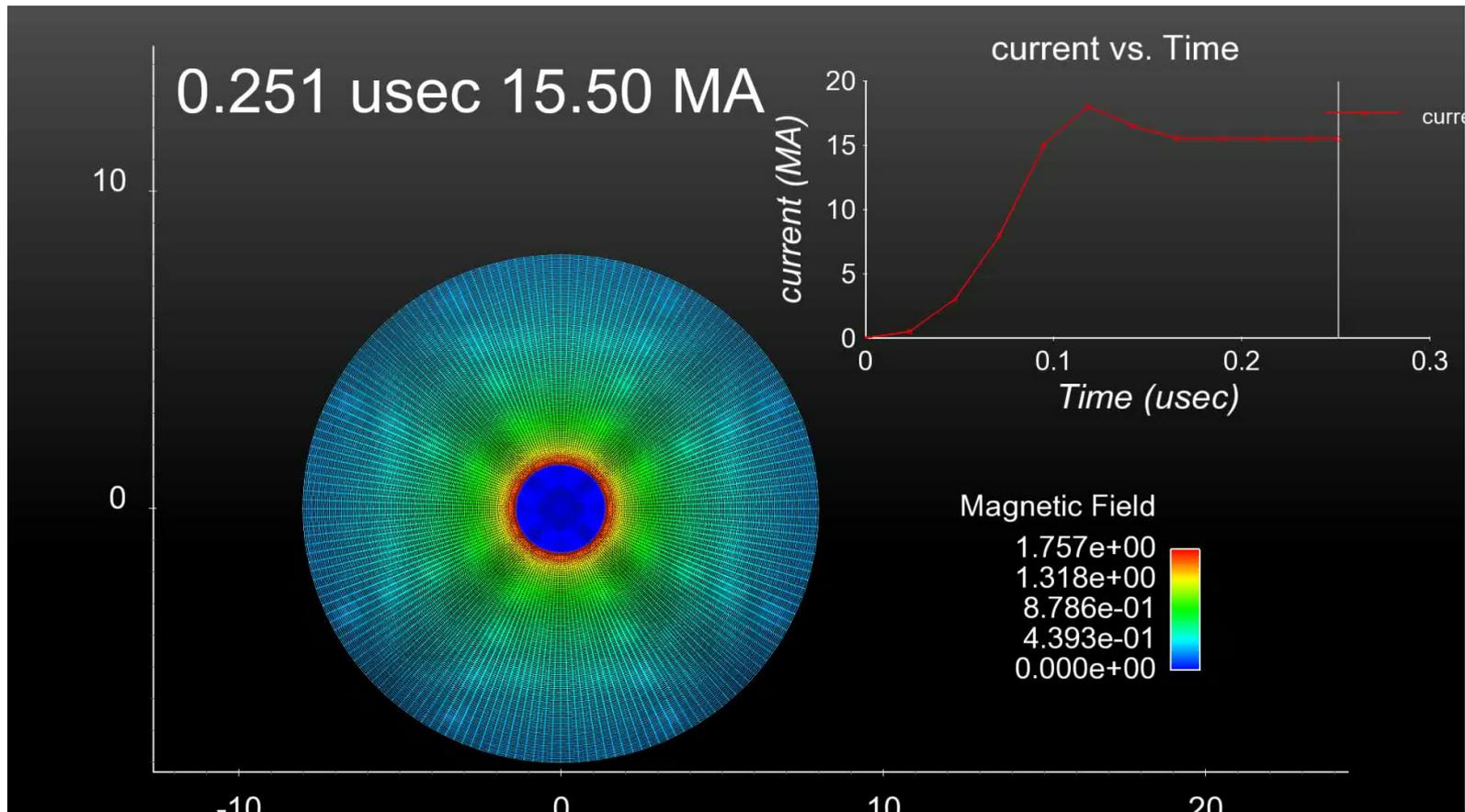


3D-MHD Package

Wire Expansion



3D-MHD Package Cable Problem



3D-MHD Package

PHELIX

